Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2016

Chemistry

Higher level

Paper 2

20 pages

Question			Answers	Notes	Total
1.	a	i	«$K_c =$» $\frac{[HOCH_2CH_2OH]}{[CO]^2 \times [H_2]^3}$ ✓		1
1.	a	ii	*Position of equilibrium*: moves to right ***OR*** favours product ✓ K_c: no change ***OR*** is a constant at constant temperature ✓		2
1.	a	iii	*Bonds broken*: $2C{\equiv}O + 3(H{-}H)$ / $2(1077\,kJ\,mol^{-1}) + 3(436\,kJ\,mol^{-1})$ / 3462 «kJ» ✓ *Bonds formed*: $2(C{-}O) + 2(O{-}H) + 4(C{-}H) + (C{-}C)$ / $2(358\,kJ\,mol^{-1}) +$ $2(463\,kJ\,mol^{-1}) + 4(414\,kJ\,mol^{-1}) + 346\,kJ\,mol^{-1}$ / 3644 «kJ» ✓ «Enthalpy change = bonds broken − bonds formed = 3462 kJ − 3644 kJ =» −182 «kJ» ✓	*Award **[3]** for correct final answer.* *Award **[2 max]** for «+»182 «kJ».*	3
1.	b	i	«$\Delta H = \Sigma\,\Delta H_f$ products $- \Sigma\,\Delta H_f$ reactants = $-454.8\,kJ\,mol^{-1} - 2(-110.5\,kJ\,mol^{-1})$ =» −233.8 «kJ» ✓		1
1.	b	ii	in (a)(iii) gas is formed and in (b)(i) liquid is formed ***OR*** products are in different states ***OR*** conversion of gas to liquid is exothermic ***OR*** conversion of liquid to gas is endothermic ***OR*** enthalpy of vapourisation needs to be taken into account ✓	*Accept product is «now» a liquid.* *Accept answers referring to bond enthalpies being means/averages.*	1

(continued)

(Question 1 continued)

Question			Answers	Notes	Total
1.	**b**	**iii**	«ΔS is negative because five mols of» gases becomes «one mol of» liquid ***OR*** increase in complexity of product «compared to reactants» ***OR*** product more ordered «than reactants» ✓	*Accept "fewer moles of gas" but not "fewer molecules".*	**1**
1.	**b**	**iv**	$\Delta S = \left(\frac{-620.1}{1000}\right)$ «kJ K^{-1}» ✓ $\Delta G = -233.8\,\text{kJ} - (298\,\text{K}\left(\frac{-620.1}{1000}\right)\text{kJ}\,\text{K}^{-1}) = -49.0$ «kJ» ✓	*Award **[2]** for correct final answer.* *Award **[1 max]** for «+»185 × 10^3.* *If −244.0 kJ used, answer is:* $\Delta G = -244.0\,\text{kJ} - (298\,\text{K}\left(\frac{-620.1}{1000}\right)\text{kJ}\,\text{K}^{-1}) =$ −59.2 «kJ» *Award **[2]** for correct final answer.*	**2**
1.	**b**	**v**	increasing T makes ΔG larger/more positive/less negative ***OR*** $-T\Delta S$ will increase ✓		**1**
1.	**c**		*Ethene*: −2 ✓ *Ethane-1,2-diol*: −1 ✓	*Do not accept 2–, 1– respectively.*	**2**

(continued)

(Question 1 continued)

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>1.</td><td>d</td><td></td><td>ethane-1,2-diol can hydrogen bond to other molecules «and ethene cannot»
OR
ethane-1,2-diol has «significantly» greater van der Waals forces ✓

hydrogen bonding is «significantly» stronger than other intermolecular forces ✓</td><td>Accept converse arguments.
Award [0] if answer implies covalent bonds are broken.</td><td>2</td></tr>
<tr><td>1.</td><td>e</td><td></td><td>acidified «potassium» dichromate«(VI)» / H^+ AND $K_2Cr_2O_7$ / H^+ AND $Cr_2O_7^{2-}$
OR
«acidified potassium» manganate(VII) / «H^+» $KMnO_4$ / «H^+» MnO_4^- ✓</td><td>Accept H_2SO_4 or H_3PO_4 for H^+.
Accept “permanganate” for “manganate(VII)”.</td><td>1</td></tr>
<tr><td>1.</td><td>f</td><td></td><td><table><tr><th></th><th>Number of signals</th><th></th><th>Splitting pattern</th></tr><tr><td>Ethanedioic acid:</td><td>1</td><td>AND</td><td>singlet ✓</td></tr><tr><td>Ethane-1,2-diol:</td><td>2 ✓</td><td></td><td>Not required</td></tr></table></td><td>Accept “none/no splitting” for singlet.</td><td>2</td></tr>
</table>

<table>
<tr><td>2.</td><td>a</td><td></td><td>Weak acid: partially dissociated/ionized «in solution/water»
AND
Strong acid: «assumed to be almost» completely/100 % dissociated/ionized «in solution/water» ✓</td><td>Accept answers relating to pH, conductivity, reactivity if solutions of equal concentrations stated.</td><td>1</td></tr>
</table>

(continued)

(Question 2 continued)

Question			Answers	Notes	Total
2.	**b**		«log scale» reduces a wide range of numbers to a small range ***OR*** simple/easy to use ***OR*** converts exponential expressions into a linear scale/simple numbers ✓	*Do **not** accept "easy for calculations".*	**1**
2.	**c**	**i**	phenolphthalein ***OR*** phenol red ✓		**1**
2.	**c**	**ii**	«$n(NaOH) = \left(\frac{14.0}{1000}\right) dm^3 \times 0.100\,mol\,dm^{-3}$ =» 1.40×10^{-3} «mol» ✓		**1**
2.	**c**	**iii**	«$\frac{1}{2} \times 1.40 \times 10^{-3}$ =» 7.00×10^{-4} «mol» ✓		**1**

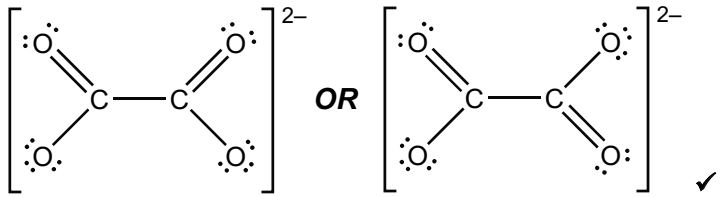
(continued)

(Question 2 continued)

Question			Answers	Notes	Total
2.	**c**	**iv**	***ALTERNATIVE 1:*** «mass of pure hydrated ethanedioic acid in each titration = 7.00×10^{-4} mol $\times$ 126.08 g mol^{-1} =» 0.0883 / 8.83×10^{-2} «g» ✓ mass of sample in each titration = «$\frac{25}{1000} \times 5.00\,g$ =» 0.125 «g» ✓ «% purity = $\frac{0.0883\,g}{0.125\,g} \times 100$ =» 70.6 «%» ✓ ***ALTERNATIVE 2:*** «mol of pure hydrated ethanedioic acid in 1 dm^3 solution = $7.00 \times 10^{-4} \times \frac{1000}{25}$ =» 2.80×10^{-2} «mol» ✓ «mass of pure hydrated ethanedioic acid in sample = 2.80×10^{-2} mol $\times$ 126.08 g mol^{-1} =» 3.53 «g» ✓ «% purity = $\frac{3.53\,g}{5.00\,g} \times 100$ =» 70.6 «%» ✓ ***ALTERNATIVE 3:*** mol of hydrated ethanedioic acid (assuming sample to be pure) = $\frac{5.00\,g}{126.08\,g\,mol^{-1}} = 0.03966$ «mol» ✓ actual amount of hydrated ethanedioic acid = «$7.00 \times 10^{-4} \times \frac{1000}{25}$ =» 2.80×10^{-2} «mol» ✓ «% purity = $\frac{2.80 \times 10^{-2}}{0.03966} \times 100$ =» 70.6 «%» ✓	*Award suitable part marks for alternative methods.* *Award **[3]** for correct final answer.* *Award **[2 max]** for 50.4 % if anhydrous ethanedioic acid assumed.*	**3**

(continued)

(Question 2 continued)

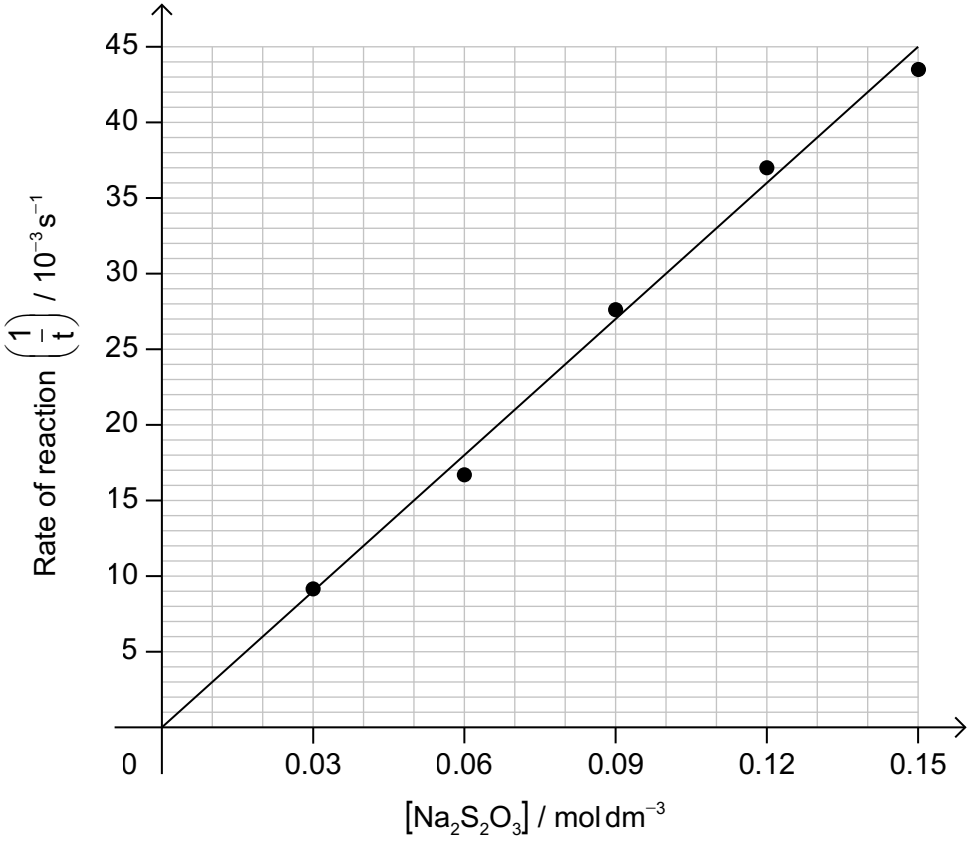
Question			Answers	Notes	Total
2.	**d**		 ***OR*** ✓	*Accept single negative charges on two O atoms singly bonded to C.* *Do not accept resonance structures.* *Allow any combination of dots/crosses or lines to represent electron pairs.*	**1**
2.	**e**		electrons delocalized **«**across the O–C–O system**»** ***OR*** resonance occurs ✓ 122 **«**pm**»** < C–O < 143 **«**pm**»** ✓	*Accept delocalized π-bond(s).* *No ECF from (d).* *Accept any answer in range 123 **«**pm**»** to 142 **«**pm**»**.* *Accept "bond intermediate between single and double bond" or "bond order 1.5".*	**2**
2.	**f**		coordinate/dative/covalent bond from O to **«**transition**»** metal **«**ion**»** ***OR*** acts as a Lewis base/nucleophile ✓ can occupy two positions ***OR*** provide two electron pairs from different **«**O**»** atoms ***OR*** form two **«**coordinate/dative/covalent**»** bonds **«**with the metal ion**»** ***OR*** chelate **«**metal/ion**»** ✓		**2**

(continued)

Question			Answers	Notes	Total
3.	a		H_2O ***AND*** (l) ✓	*Do **not** accept H_2O (aq).*	**1**
3.	b		SO_2(g) is an irritant/causes breathing problems ***OR*** SO_2(g) is poisonous/toxic ✓	*Accept SO_2 (g) is acidic but do not accept "causes acid rain".* *Accept SO_2 (g) is harmful.* *Accept SO_2 (g) has a foul/pungent smell.*	**1**
3.	c		$n(HCl) = \text{«} \frac{10.0}{1000} dm^3 \times 2.00\,mol\,dm^{-3} = \text{»}\ 0.0200 / 2.00 \times 10^{-2}$ «mol» ***AND*** $n(Na_2S_2O_3) = \text{«} \frac{50}{1000} dm^3 \times 0.150\,mol \times dm^{-3} = \text{»}\ 0.00750 / 7.50 \times 10^{-3}$ «mol» ✓ 0.0200 «mol» > 0.0150 «mol» ***OR*** 2.00×10^{-2} «mol» $> 2 \times 7.50 \times 10^{-3}$ «mol» ***OR*** $\frac{1}{2} \times 2.00 \times 10^{-2}$ «mol» > 7.50×10^{-3} «mol» ✓	*Accept answers based on volume of solutions required for complete reaction.* *Award **[2]** for second marking point.* *Do **not** award M2 unless factor of 2 (or half) is used.*	**2**

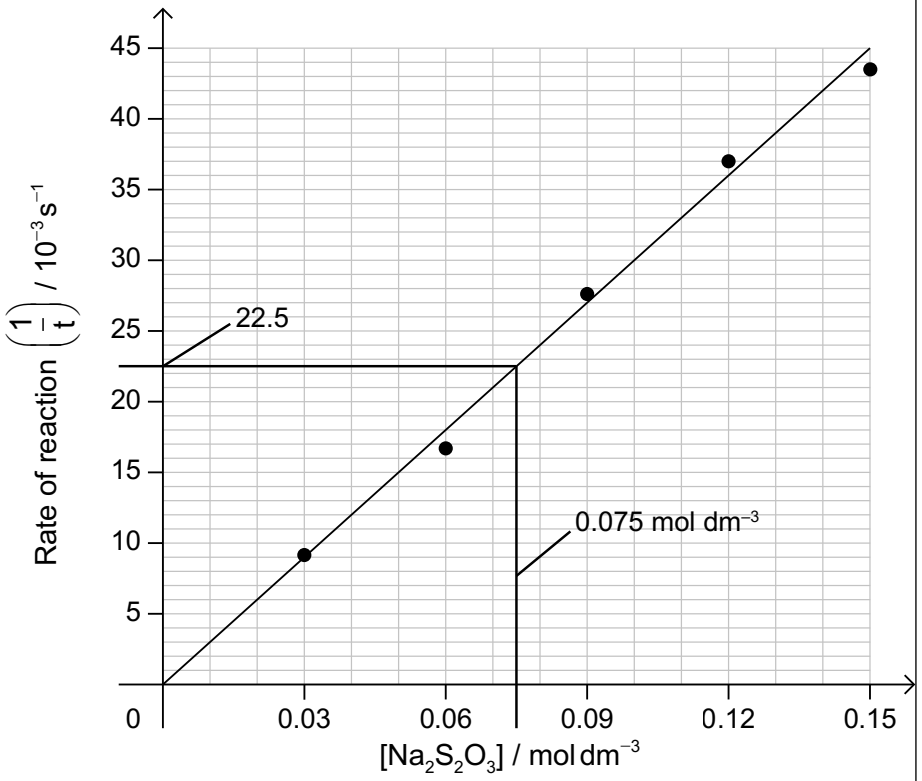
(continued)

(Question 3 continued)

Question			Answers	Notes	Total
3.	d		 five points plotted correctly ✓ best fit line drawn with ruler, going through the origin ✓		**2**

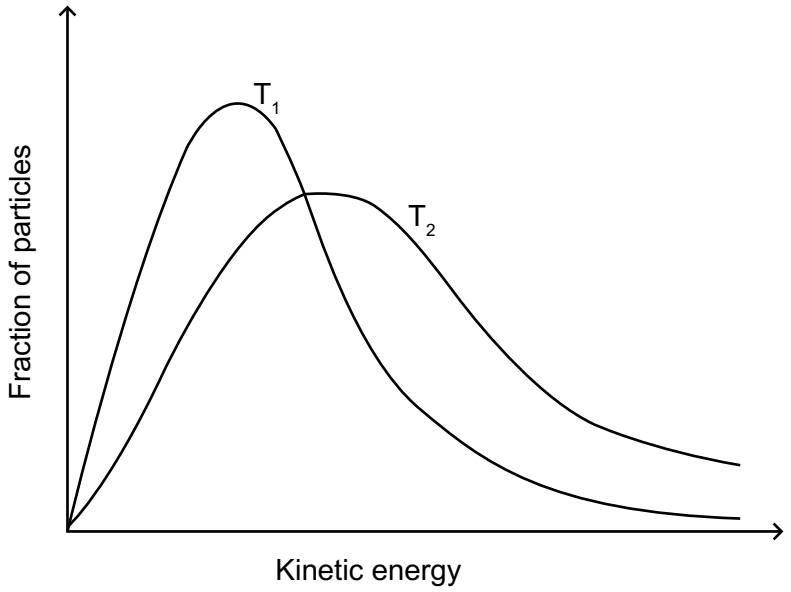
(continued)

(Question 3 continued)

Question			Answers	Notes	Total
3.	**e**	**i**	first order ✓ **«**because**»** $[Na_2S_2O_3]$ is **«**directly**»** proportional to rate of reaction **«**$\frac{1}{t}$**»** ✓	*Do not accept "linear" for M2.*	**2**
3.	**e**	**ii**	rate = $k\,[Na_2S_2O_3][HCl]$ ✓		**1**
3.	**f**		 22.5×10^{-3} **«**s^{-1}**»** ✓ **«**Time = $\frac{1}{22.5 \times 10^{-3}}$ **=»** 44.4 **«**s**»** ✓	*Award **[2]** for correct final answer.* *Accept value based on candidate's graph.* *Award M2 as ECF from M1.* *Award **[1 max]** for methods involving taking mean of appropriate pairs of* $\frac{1}{t}$ *values.* *Award **[0]** for taking mean of pairs of time values.* *Award **[2]** for answers between 42.4 and 46.4 «s».*	**2**

(continued)

(Question 3 continued)

Question			Answers	Notes	Total
3.	g	i	 correctly labelled axes ✓ peak of T_2 curve lower ***AND*** to the right of T_1 curve ✓	*Accept "probability «density» / number of particles / N / fraction" on y-axis.* *Accept "kinetic E/KE/E_k" but not **just** "Energy/E" on x-axis.*	**2**

(continued)

(Question 3 continued)

Question			Answers	Notes	Total
3.	**g**	**ii**	greater proportion of molecules have $E \geq E_a$ or $E > E_a$ ***OR*** greater area under curve to the right of the E_a ✓ greater frequency of collisions **«**between molecules**»** ***OR*** more collisions per unit time/second ✓	*Accept more molecules have energy greater than E_a.* *Do **not** accept just "particles have greater kinetic energy".* *Accept "rate/chance/probability/likelihood" instead of "frequency".* *Accept suitably shaded/annotated diagram.* *Do **not** accept just "more collisions".*	**2**
3.	**h**		shorter reaction time so larger «%» error in timing/seeing when mark disappears ✓	*Accept cooling of reaction mixture during course of reaction.*	**1**

(continued)

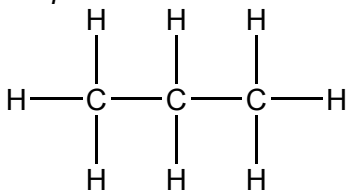
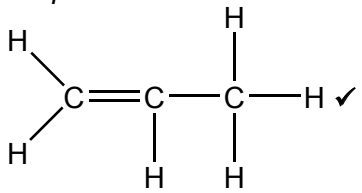
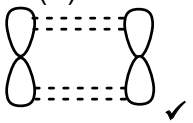
Question			Answers	Notes	Total
4.	a		$^{26}_{12}Mg$ ✓		1
4.	b		«A_r =» $\frac{24 \times 78.60 + 25 \times 10.11 + 26 \times 11.29}{100}$ ✓ «= 24.3269 =» 24.33 ✓	*Award **[2]** for correct final answer.* *Do **not** accept data booklet value (24.31).*	2
4.	c		contamination with sodium/other «compounds» ✓		1
4.	d	i	energy levels are closer together <u>at high energy / high frequency / short wavelength</u> ✓		1
4.	d	ii	ionisation energy ✓		1
4.	e		$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(s)$ ***OR*** $MgO(s) + H_2O(l) \rightarrow Mg^{2+}(aq) + 2OH^-(aq)$ ✓	*Accept* $\rightleftharpoons$.	1
4.	f		from basic to acidic ✓ through amphoteric ✓	*Accept "alkali/alkaline" for "basic".* *Accept "oxides of Na and Mg: basic **AND** oxide of Al: amphoteric" for M1.* *Accept "oxides of non-metals/Si to Cl acidic" for M2.* *Do **not** accept just "become more acidic".*	2
4.	g		Mg_3N_2 ✓	*Accept MgO_2, $Mg(OH)_2$, $Mg(NO_x)_2$, $MgCO_3$.*	1
4.	h		«3-D/giant» regularly repeating arrangement «of ions» ***OR*** lattice «of ions» ✓ electrostatic attraction between oppositely charged ions ***OR*** electrostatic attraction between Mg^{2+} and O^{2-} ions ✓	*Accept "giant" for M1 unless "giant covalent" stated.* *Do **not** accept "ionic" without description.*	2
4.	i	i	*Anode (positive electrode):* $2Cl^- \rightarrow Cl_2(g) + 2e^-$ ✓ *Cathode (negative electrode):* $Mg^{2+} + 2e^- \rightarrow Mg(l)$ ✓	*Penalize missing/incorrect state symbols at Cl_2 and Mg once only.* *Award **[1 max]** if equations are at wrong electrodes.* *Accept $Mg(g)$.*	2

(continued)

(Question 4 continued)

Question			Answers	Notes	Total
4.	**i**	**ii**	reduction ✓		**1**
4.	**i**	**iii**	*Anode (positive electrode)*: oxygen/O_2 ***OR*** hydrogen ion/proton/H^+ ***AND*** oxygen/O_2 ✓ *Cathode (negative electrode)*: hydrogen/H_2 ***OR*** hydroxide **«**ion**»**/OH^- ***AND*** hydrogen/H_2 ✓	*Award **[1 max]** if correct products given at wrong electrodes.*	**2**
4.	**j**		*Any two of:* **«**inert**»** Pt electrode ***OR*** platinum black conductor ✓ 1 mol dm^{-3} H^+(aq) ✓ H_2(g) at 100 kPa ✓	*Accept 1 atm H_2(g).* *Accept 1 bar H_2(g)* *Accept a labelled diagram.* *Ignore temperature if it is specified.*	**2 max**
4.	**k**	**i**	$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$ ✓		**1**
4.	**k**	**ii**	**«**+0.34 V − (−2.37 V) = +**»**2.71 **«**V**»** ✓		**1**
4.	**k**	**iii**	cell potential increases ✓ reaction **«**in Q4(k)(i)**»** moves to the right ***OR*** potential of the copper half-cell increases/becomes more positive ✓	*Accept correct answers based on the Nernst equation.*	**2**

(continued)

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>5.</td><td>a</td><td></td><td>Propane:
 
AND
Propene:
  </td><td></td><td>1</td></tr>
<tr><td>5.</td><td>b</td><td>i</td><td>Sigma (σ):
 
Pi (π):
  </td><td></td><td>2</td></tr>
<tr><td>5.</td><td>b</td><td>ii</td><td><table><tr><th></th><th>Number of sigma (σ) bonds</th><th>Number of pi (π) bonds</th></tr><tr><td>Propane</td><td>10</td><td>0</td></tr><tr><td>Propene</td><td>8</td><td>1</td></tr></table></td><td>Award [1] for two or three correct answers.
Award [2] for all four correct.</td><td>2</td></tr>
</table>

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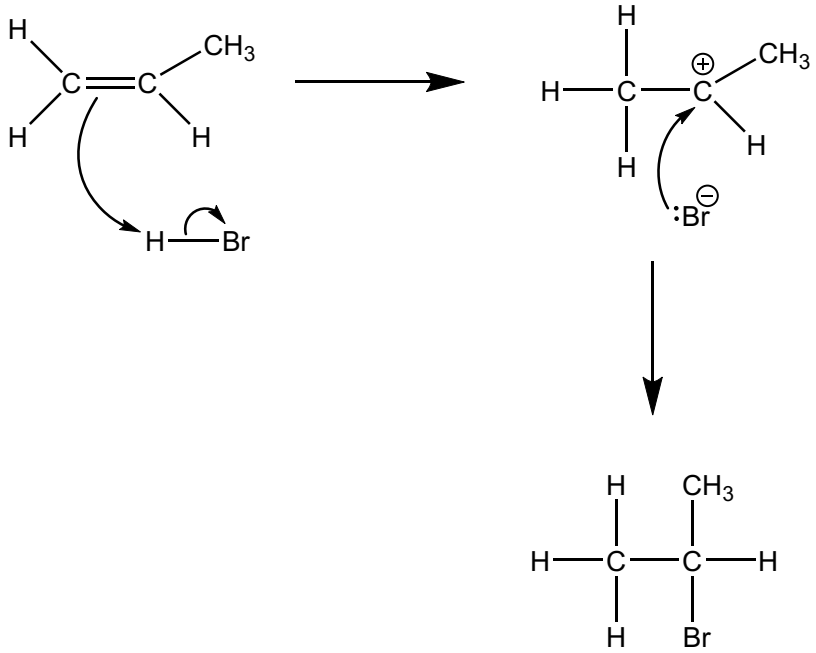
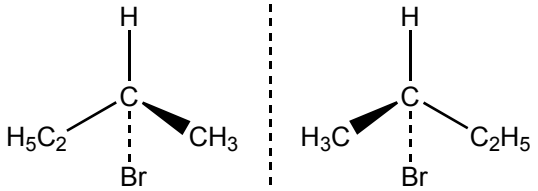
(Question 5 continued)

Question			Answers	Notes	Total
5.	**c**	**i**	$C_3H_8 + Br_2 \rightarrow C_3H_7Br + HBr$ ✓ **«**sun**»**light/UV/$h\nu$ ***OR*** high temperature ✓	*Do not accept "reflux" for M2.*	**2**
5.	**c**	**ii**	$C_3H_6 + Br_2 \rightarrow C_3H_6Br_2$ ✓		**1**
5.	**c**	**iii**	*Propane*: **«**free radical**»** substitution / S_R ***AND*** *Propene*: **«**electrophilic**»** addition / A_E ✓		**1**
5.	**d**		 curly arrow going from C=C to H of HBr **and** curly arrow showing Br leaving ✓ representation of carbocation ✓ curly arrow going from lone pair/negative charge on Br^- to C^+ ✓	*Award **[2 max]** for formation of 1-bromopropane.*	**3**

(continued)

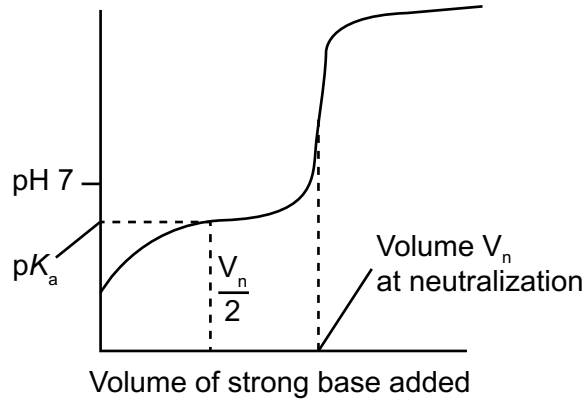
Question			Answers	Notes	Total
6.	a		 correct isomer ✓ mirror image shown clearly ✓		**2**
6.	b		S_N2 would give inversion of configuration «almost 100 %» ***OR*** S_N1 would give «approximately» 50 % of each ✓ so mechanism is a mixture of both mechanisms ✓		**2**
6.	c		C–I bond «longer, so» weaker «than C–Br bond» ***OR*** I^- is a better leaving group than Br^- ✓		**1**

(continued)

Question			Answers	Notes	Total
7.	a		*Calculation*: ***ALTERNATIVE 1:*** $[H^+] = (K_a \times [HA])^{1/2} / (1.6 \times 10^{-4} \times 0.0100)^{1/2} / 1.3 \times 10^{-3}$ **«**mol dm^{-3}**»** ✓ pH = **«**$-\log_{10}[H^+]$ ≈**»** 2.9 ✓ ***ALTERNATIVE 2:*** $pH = 0.5(pK_a - \log_{10}[HA])$ ✓ pH = 2.9 ✓ *Assumption*: ionisation is << 0.0100 so $0.0100 - [A^-] \approx 0.0100$ ***OR*** $[HA]_{eqm} = [HA]_{initial}$ ***OR*** all H^+ ions in the solution come from the acid **«**and not from the self-ionisation of water**»** ***OR*** $[H^+] = [HCOO^-]$ ✓	*Award **[2]** for correct final answer.* *Do not accept partial dissociation.*	**3**

(continued)

(Question 7 continued)

Question			Answers	Notes	Total
	b	**i**	 correct shape of graph ✓ pH at half neutralization/equivalence ✓	*M1: must show buffer region at pH < 7 and equivalence at pH > 7.* *Accept graph starting from where two axes meet as pH scale is not specified.*	**2**
	b	**ii**	***ALTERNATIVE 1:*** $HCOOH \rightleftharpoons HCOO^- + H^+$ ✓ H^+ ions consumed in reaction with OH^- are produced again as equilibrium moves to the right **«**so $[H^+]$ remains almost unchanged**»** ✓ ***ALTERNATIVE 2:*** $HCOOH + OH^- \rightleftharpoons HCOO^- + H_2O$ ✓ added OH^- are neutralized by HCOOH ***OR*** strong base replaced by weak base ✓	*Accept HA or any other weak acid in equations.* *Equilibrium sign must be included in equation for M1.*	**2**